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SEASONAL DISTRIBUTION AND RELATIVE ABUNDANCE OF PLANKTONIC-STAGE SHRIMP (*Penaeus spp.*) IN THE NORTHWESTERN GULF OF MEXICO, 1961[1]

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ABSTRACT

Planktonic stages of shrimp (*Penaeus* spp.) were sampled systematically in the Gulf of Mexico near Galveston, Tex., during January-December 1961. The Gulf-V plankton net was used every 3 weeks at stations established at water depths of 14, 27, 46, and 82 m. The study area encompassed about 20,725 km.^{2}

Trends in seasonal abundance of larvae varied with depth. At 14-m. stations a unimodal trend was observed, and peak abundance was during May to September. In deeper waters a bimodal trend was apparent; peak abundance extended from late summer through fall. At all depths, trends in larval abundance increased as bottom water temperatures increased.

Postlarvae were taken in plankton tows during January to April but were most abundant during August to December.

Distinct shifts in the areal distribution of larvae and postlarvae were apparent. During January to March, larvae were restricted to water deeper than 14 m. and shallower than 82 m. whereas postlarvae occurred in all depths. This situation was generally reversed in April to August, when larvae were at all depths, but the distribution of postlarvae was restricted. In September to December, distribution patterns of larvae and postlarvae were generally similar.

On the basis of this study and laboratory experiments on larval development and postlarval growth rates as affected by temperature, support is given to the premise that brown shrimp larvae or postlarvae, or both, overwinter in waters over the Continental Shelf.

The shrimp fishery in the Gulf of Mexico has expanded rapidly within the past 20 years and is now the most valuable fishery in the United States. Since 1950 the yearly harvest has fluctuated around 200 million pounds. Although about six members of the family Penaeidae are taken in the fishery, only three species—the brown shrimp, *Penaeus aztecus* Ives; the pink shrimp, *P. duorarum* Burkenroad; and the white shrimp, *P. setiferus* (Linnaeus)—contribute significantly to the catch.

Before 1959, research designed to provide management programs for optimum utilization of these shrimp stocks did not increase at the same rate as the value of this fishery. In 1959, however, the Bureau of Commercial Fisheries began a program of shrimp research that has expanded considerably during the past 7 years. The general aims of the program were stated by Kutkuhn (1963). The present study of the seasonal distribution and abundance of planktonic-stage *Penaeus* spp. in the northwestern Gulf of Mexico is a part of this research.

Considerable information has been published on the early life history of the white shrimp (Weymouth, Lindner, and Anderson, 1933; Burkenroad, 1934; Pearson, 1939; Anderson, King, and Lindner, 1949). Brown and pink shrimp have similar early life histories, although bathymetric and geographic distributions of the adults are different. In general, these shrimp spawn in waters over the Continental Shelf; brown shrimp spawn at least as far as 198 km. (110 nautical miles) offshore in depths as great as 110 m. The eggs are slightly denser than sea water and settle to the bottom when spawned. After hatching, the young become planktonic and develop through three larval (naupliar, protozoeal, and mysis) and several postlarval stages. They enter the estuaries as postlarvae, grow rapidly to subadult size, and then migrate offshore to complete their growth and spawn.

The earlier work on white shrimp provides

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little information about the seasonal distribution, abundance, and taxonomy of planktonic stages of penaeids in the Gulf of Mexico. Until recently the most extensive work available was that of Pearson (1939), who not only described planktonic stages of several penaeids from specimens obtained from plankton hauls, but also provided information on seasonal occurrence and distribution of postlarval white shrimp. More recently, descriptions of plank-

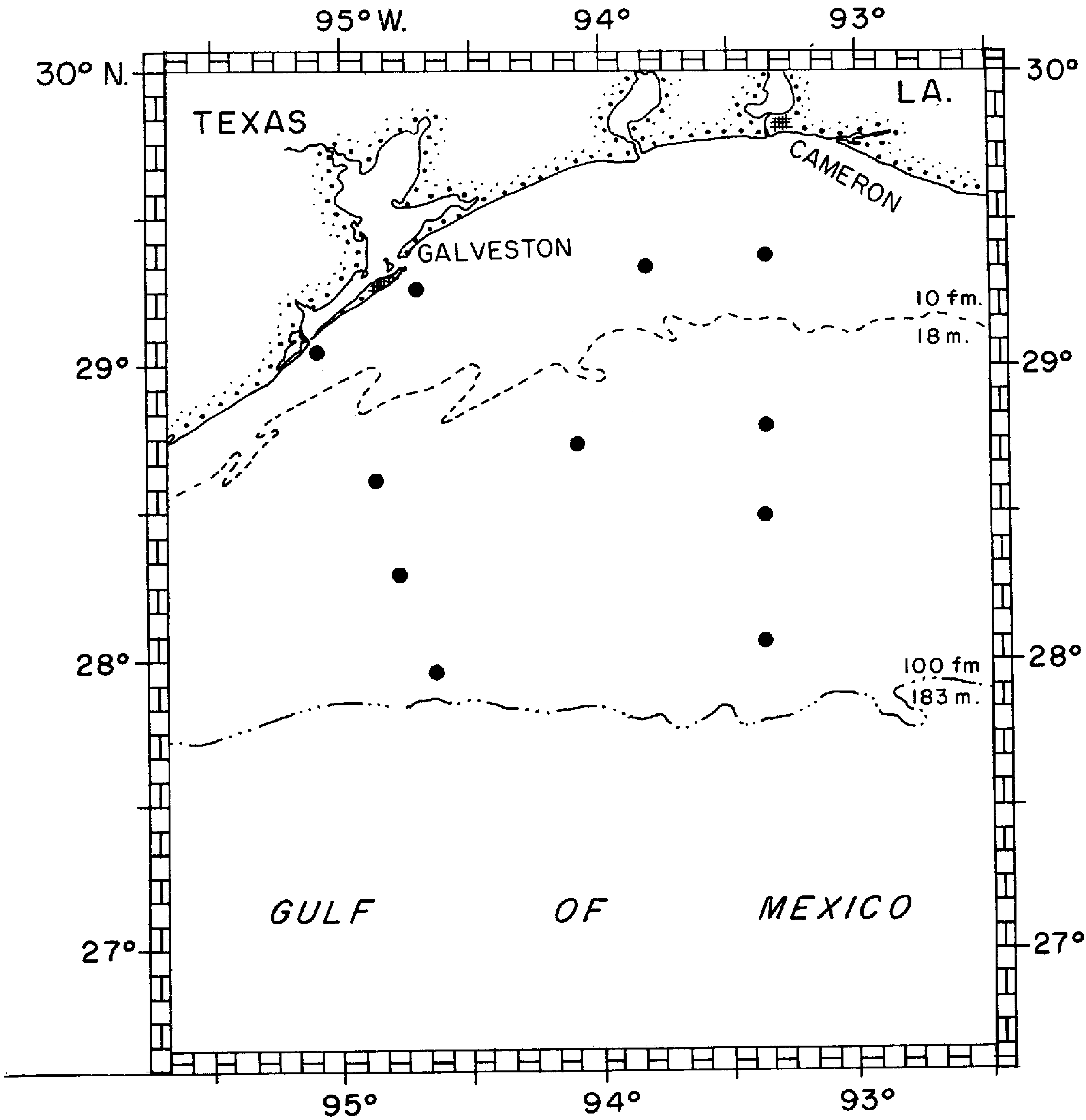


FIGURE 1.—Location of sampling stations for shrimp larvae in 1961.

tonic stages have been published for the pink shrimp by Dobkin (1961); for the seabob, *Xiphopeneus kroyeri* (Heller) by Renfro and Cook (1963); and for the rock shrimp, *Sicyonia brevirostris* Stimpson by Cook and Murphy (1965). All three species occur in the northern Gulf.

Because of the limited amount of taxonomic material available, as well as the occurrence of about 35 penaeids (Burkenroad, 1936; Springer and Bullis, 1956; Bullis and Thompson, 1965) in the Gulf of Mexico, one of the major problems in this study was the identification of the planktonic stages. Although H. L. Cook (personal communication) has been able to rear the planktonic stages of brown, white, and pink shrimp, differentiation of the species among these forms is not yet possible. Consequently, penaeids encountered in plankton samples were identified only to genus by using the generic key developed by Cook (1966a). Data on only *Penaeus* spp. are presented in this report.

METHODS AND MATERIALS

STUDY AREA

During 1961, sampling was conducted at 11 stations (fig. 1) over an area of about 20,725 km.^{2} (8,000 square miles). During cruises at 3-week intervals, plankton hauls were made at stations where water depth was about 14, 27, 46, and 82 m.

SAMPLING GEAR AND CALIBRATION

Plankton samples were obtained with the Gulf-V plankton net described by Arnold (1959). This gear consists of a metal frame, to which a conical monel net with a mesh size of 31.5 strands per centimeter is attached. The diameter of the net mouth is about 40.5 cm. Plankton was collected in a cup attached to the end of the net. After each tow the net was thoroughly washed down and the plankton removed and preserved in 5 percent Formalin.[2]

Estimates of water volume filtered during each tow were calculated from a flowmeter positioned in the center of the net mouth. Both TSK and Atlas flowmeters, calibrated by the technique outlined by Ahlstrom (1948), were used. Each tow lasted 20 minutes, and towing speeds averaged 4.6 km. per hour (2.5 knots). Flowmeter readings indicated that during each tow the net filtered about 100 m.^{3} of water. Catches are reported in numbers of organisms per 100 m.^{3} of water strained.

DEPTHS FISHED AND TOWING CABLE PROFILE

Each of four depths was fished for 5 minutes during each tow: 3 m. above the bottom, two intermediate depths, and 3 m. below the surface. The two intermediate depths fished were equally spaced vertically within the water column and depended on the total water depth. Sampling depths were determined by the trigonometric function of the wire angle and length of towing cable. Realizing that this technique assumed the profile of the towing cable to be a straight line, we attached a bathykymograph [3] (Model T-1a, Marine Advisors, Inc.) to a Gulf-V net and made tests to determine the reliability of this technique. Results are given in table 1.

A plot of mean actual depths vs. calculated depths provides an estimate of the error between the actual and assumed towing cable profiles (fig. 2). Agreement was close to a

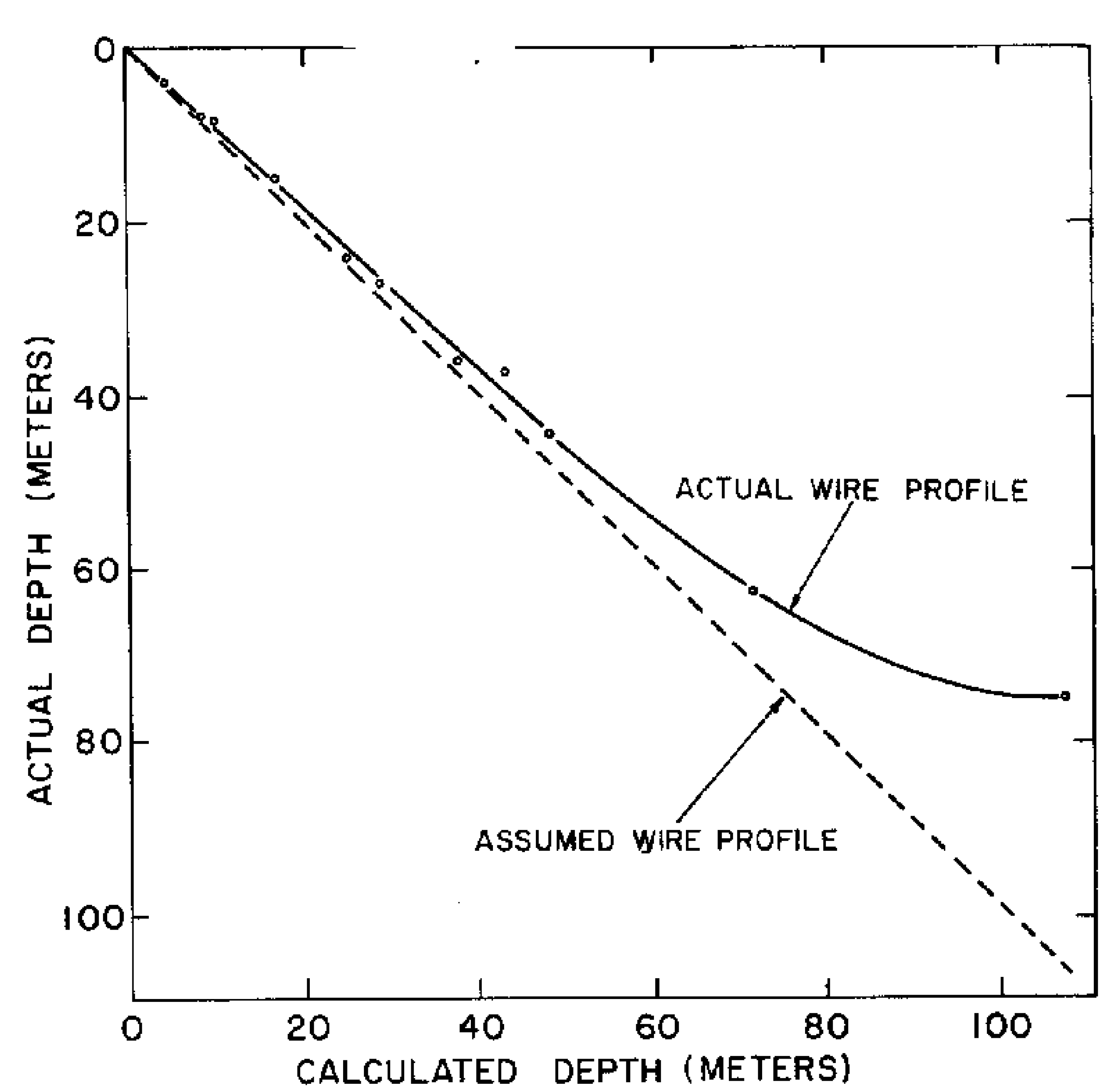


FIGURE 2.—The calculated and actual profiles of the towing cable attached to a Gulf-V plankton net.

[2] Trade names referred to in this publication do not imply endorsement of commercial products.

[3] Calibration accuracy ± 1 percent full scale. Sensitivity 0.5 percent of full scale.

TABLE 1.—*Results of tests to determine reliability of calculated sampling depths attained by using wire angle and length of towing cable*

Observations	Calculated depth	Average actual depth	Range of observed depths
Number	*Meters*	*Meters*	*Meters*
5	3	3	2–4
1	5	4	–
1	8	7	–
7	10	8	4–10
16	17	17	8–22
16	25	24	17–35
10	29	27	24–32
3	38	36	25–48
10	43	37	32–45
10	48	44	35–57
13	71	63	55–77
3	107	75	64–88

depth of 50 m., but became progressively poorer beyond this depth. Consequently, the deepest samples from stations in 82 m. of water probably were taken at a distance above the bottom that averaged considerably greater than the intended 3 m.

DAY VS. NIGHT CATCHES OF PLANKTONIC-STAGE *PENAEUS* SPP.

The oblique-step tow was used throughout this study in an attempt to eliminate possible differences in day and night catches caused by diurnal migrations of larval shrimp. Russell (1925, 1928) has shown that, in general, decapod larvae undergo diurnal vertical migrations. More recently Temple and Fischer (1965) observed similar migrations in planktonic stages of penaeid shrimp in the northwestern Gulf of Mexico when temperature profiles (bathythermograph traces) indicated a stratified water column.

Hydrographic conditions over the Continental Shelf in the northwestern Gulf of Mexico appear to be seasonal, as there are definite times when temperatures of the waters are either stratified or isothermal (Harrington, 1965). The time and extent of these seasons vary, however, depending on total water depth and to some degree on distance offshore. In general, water is stratified at a total depth of 14 and 27 m. during May to July, at 46 m. during May to September, and at 82 m. during April to October. In other months, temperatures are essentially isothermal.

Average day and night catches were calculated for stations at which water was stratified and for those at which the water column was isothermal (table 2). Hauls with no shrimp were excluded. Catches made at the 82-m. stations also were excluded because no larvae appeared to be present during either the day or night at certain times of the year, and water deeper than 50 m. was not sampled adequately. After a test of homogeneity indicated a need for logarithmic transformation of the data, statistical treatment revealed that day and night catches did not differ significantly during either stratified or isothermal conditions. As used in this study, the oblique-step tow apparently did prevent possible differences in day and night catches caused by diurnal migrations of larval shrimp.

TABLE 2.—*T-test of average catches of planktonic-stage Penaeus spp. in day and night samples during different temperature conditions in the northwestern Gulf of Mexico, 1961*

[Number per 100 m.^{3} of water strained]

Stage	Water stratified			Water isothermal		
	Day	Night	"t" [1]	Day	Night	"t" [1]
Nauplius	12.5	10.0	0.468	24.1	14.5	0.948
Protozoea	67.2	42.7	.314	28.0	54.7	.515
Mysis	22.2	11.7	.673	13.8	12.3	.263
Postlarva	.0	7.3	-------	15.4	12.6	.345
All stages	64.5	19.2	1.214	41.7	38.8	.092

[1] "t" value at .05 level.

ASSOCIATED PHYSICAL DATA

In addition to the plankton sampling at each station, temperature and salinity measurements were taken with a Foxboro Dynalog at selected depths. Temperatures were recorded to 0.1° C. and salinities to 0.1 p.p.t. (parts per thousand).

LABORATORY PROCEDURES

In the laboratory, plankton samples were transferred from 32-fluid-ounce (9.6 dl.) jars to 8-fluid-ounce (2.4 dl.) jars, and the 5 percent Formalin solution was replaced by a new 5 percent solution with glycerin and borax added. Each sample was examined under a microscope at magnifications that ranged from 0.7X to 6.0X. All planktonic stages of penaeids were removed, sorted to developmental stage, identified to genus, and counted. Postlarvae of the genus *Penaeus* were measured and identified to species by using characteristics described by Baxter and Renfro (1967).

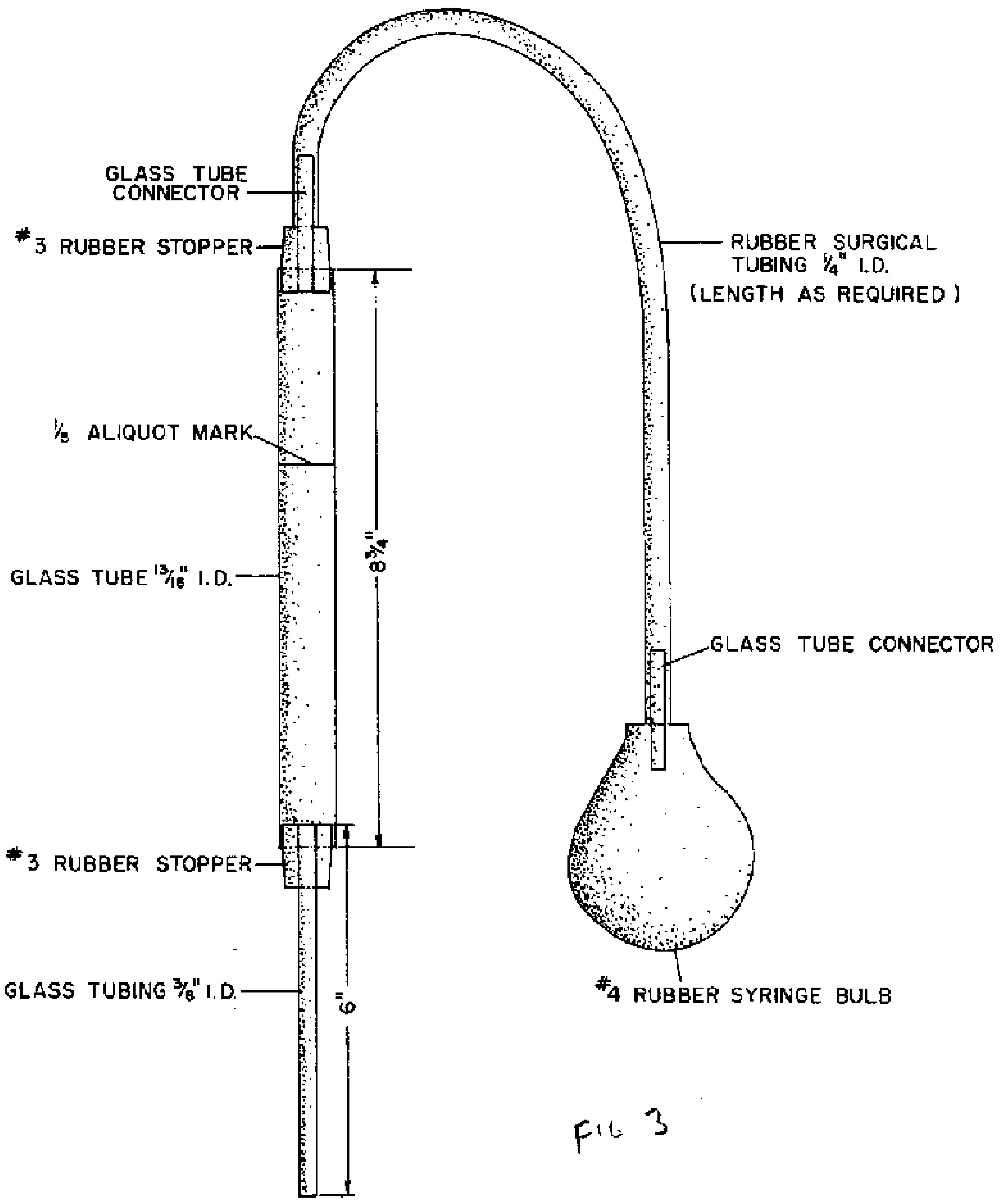


FIGURE 3.—Syringe device used for subsampling plankton.

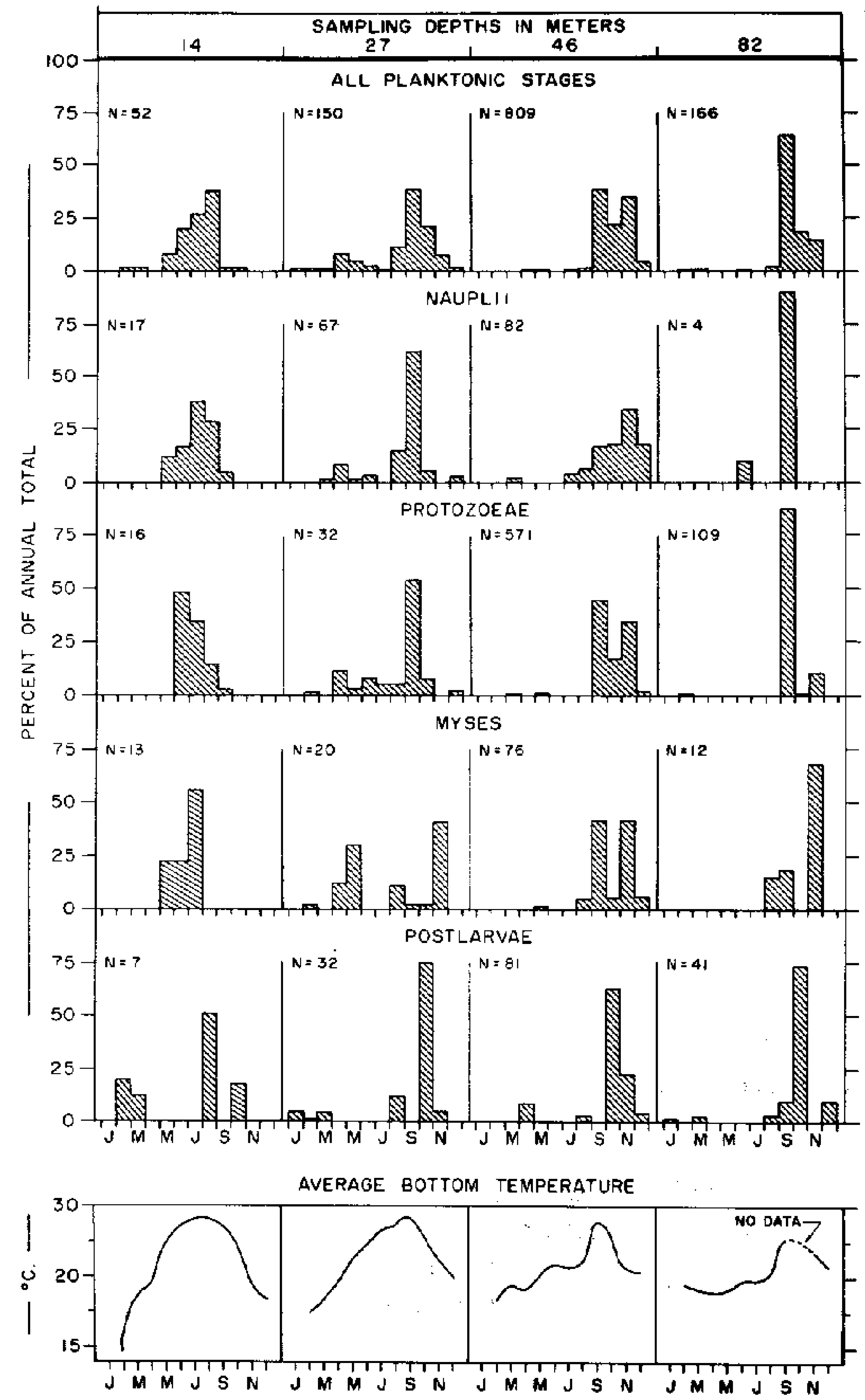


FIGURE 4.—Seasonal abundance trends of planktonic-stage *Penaeus* spp. and average bottom temperature by station depths in 1961.

The amount of each sample examined depended on the settled volume of plankton. Hauls in which the settled volume was less than 25 ml. were examined in their entirety; when sample volume exceeded 25 ml., only one-fifth of the total sample was examined. Aliquots were extracted directly from the samples with a syringe device (fig. 3). Subsampling accuracy was checked by applying chi-square tests to pooled counts from aliquot sizes ranging from one-fifth to four-fifths of the total sample (table 3). These tests indicated that the subsampling technique provided adequate estimates of total counts.

TRENDS IN SEASONAL ABUNDANCE AND THEIR IMPLICATIONS

Seasonal trends in abundance for all planktonic stages of *Penaeus* spp. were determined for 14-, 27-, 46-, and 82-m. stations (table 4). Cumulative yearly totals showed that the greatest catch per unit of effort for each stage was made at the 46-m. stations.

Distinct trends in abundance for all planktonic stages combined were evident at each of the four depths (fig. 4). Two peaks of abundance were evident at each depth, but abundance was always much greater during the second peak. The time of greatest abundance was during May to August in 14 m. of water, August to November in 27 m., and September to November in 46 and 82 m. In general, peak abundance was attained at a progressively later time in the year with an increase in water depth. In addition, observed increases in abundance and increases in temperature of bottom waters at each depth were closely parallel, suggesting a possible direct relation.

At the 27-, 46-, and 82-m. stations, larval stages, excluding postlarvae, were taken in

TABLE 3.—*Results of tests to determine subsampling accuracy for obtaining total counts of larval shrimp in plankton samples*

Larvae in sample	Fraction of sample examined							
	One-fifth		Two-fifths		Three-fifths		Four-fifths	
	Samples tested	Chi-square value	Samples tested	Chi-square value	Samples tested	Chi-square value	Samples tested	Chi-square value
Number	*Number*		*Number*		*Number*		*Number*	
1–10	7	[1] 6.155	5	0.630	2	0.060	2	1.841
11–49	22	.156	7	.070	3	.205	2	.033
50–99	9	.312	5	.090	4	1.370	4	.027
100–199	10	2.056	8	.873	8	.005	6	.986
200–299	3	1.488	2	3.195	2	2.111	2	[1] 4.380
600–699	1	.010	1	1.145				
900–999	1	.385	1	.132	1	.312	1	1.204

[1] Significant at .05 level; chi-square table value = 3.841.

plankton hauls during both periods of increased abundance. At 14-m. stations, however, larval stages were encountered only during May to September. Postlarval stages made up the entire catch in February and March. Exclusion of postlarvae from the catches, consequently, results in a unimodal trend in larval abundance at the shallowest stations and a bimodal trend at deeper stations.

The difference between depths in timing of peak larval abundance is believed caused by the bathymetric distribution of the white and brown shrimp, which constitute about 98 percent of the total commercial shrimp landings from this area. Lindner and Anderson (1956), reporting on the bathymetric distribution of white shrimp in Louisiana and Texas waters, indicated that although a few adults may be in water deeper than 27 m., the bulk of the population is in shallower water. The spawning period in May to August, indicated by the occurrence of larvae in our plankton hauls at 14- and 27-m. stations, agrees closely with the spawning season of white shrimp along the Louisiana and Texas coasts postulated by Lindner and Anderson (1956).

Periods of increased larval abundance measured at 27-, 46-, and 82-m. stations reflect, we believe, the spawning activity of brown shrimp. The bathymetric distribution of adult brown shrimp along the Texas and Louisiana coasts can be inferred from the statistics of commercial landings supplied by the U.S. Fish and Wildlife Service. These data reveal that although brown shrimp concentrations vary seasonally, the greatest number of adults usually are in water 27 to 46 m. deep during the fall. In addition, Renfro and Brusher (manuscript in preparation),[4] who determined

[4] "Seasonal abundance, size distribution, and spawning of penaeid shrimp in the northwestern Gulf of Mexico," by William C. Renfro and Harold A. Brusher, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex.

TABLE 4.—*Monthly catch of Penaeus spp. by depth, 1961*

[Number of shrimp per 100 $m.^3$ of water filtered]

Depth and planktonic stage	Month												Cumulative total
	January	February	March	April	May	June	July	August	September	October	November	December	
14 meters:													
All stages	0.0	1.4	0.7	0.0	4.4	10.5	13.9	18.6	1.0	1.2	0.0	0.0	51.7
Nauplii	.0	.0	.0	.0	2.2	2.9	6.5	4.7	.6	.0	.0	.0	16.9
Protozoeae	.0	.0	.0	.0	.0	7.6	5.2	2.3	.4	.0	.0	.0	15.5
Myses	.0	.0	.0	.0	2.2	.0	2.2	8.1	.0	.0	.0	.0	12.5
Postlarvae	.0	1.4	.7	.0	.0	.0	.0	3.5	.0	1.2	.0	.0	6.8
27 meters:													
All stages	1.3	.9	2.1	11.6	7.8	4.5	1.9	17.9	59.2	31.0	9.8	2.2	150.2
Nauplii	.0	.0	.7	5.8	1.0	1.9	.0	10.2	41.9	4.3	.0	1.1	66.9
Protozoeae	.0	.3	.0	3.3	.9	2.6	1.9	1.8	16.9	2.7	.0	1.1	31.5
Myses	.0	.3	.0	2.5	5.9	.0	.0	2.2	.4	.5	8.2	.0	20.0
Postlarvae	1.3	.3	1.4	.0	.0	.0	.0	3.7	.0	23.5	1.6	.0	31.8
46 meters:													
All stages	.0	.0	3.3	6.3	3.6	.0	3.3	11.8	303.9	166.6	278.2	31.9	808.9
Nauplii	.0	.0	2.6	.0	.0	.0	3.3	4.7	13.7	14.5	28.2	14.6	81.6
Protozoeae	.0	.0	.7	.0	2.4	.0	.0	1.2	258.3	97.8	200.7	9.4	570.5
Myses	.0	.0	.0	.0	1.2	.0	.0	3.5	31.9	3.6	31.7	4.2	76.1
Postlarvae	.0	.0	.0	6.3	.0	.0	.0	2.4	.0	50.7	17.6	3.7	80.7
82 meters:													
All stages	.0	1.3	.9	.0	.0	.4	.0	3.1	105.1	30.9	24.4	.0	166.1
Nauplii	.0	.0	.0	.0	.0	.4	.0	.0	3.4	.0	.0	.0	3.8
Protozoeae	.0	.9	.0	.0	.0	.0	.0	.0	95.4	.5	12.2	.0	109.0
Myses	.0	.0	.0	.0	.0	.0	.0	1.7	2.1	.0	8.1	.0	11.9
Postlarvae	.0	.4	.9	.0	.0	.0	.0	1.4	4.2	30.4	4.1	.0	41.4
Cumulative total—all stages	1.3	3.6	7.0	17.9	15.8	15.4	19.1	51.4	469.2	229.7	312.4	34.1	

spawning seasons of the brown shrimp by ovarian examination, reported that ripe brown shrimp rarely occur in water less than 27 m. deep along the Texas and Louisiana coasts.

SPAWNING IN RELATION TO BOTTOM TEMPERATURES

Because penaeids are poikilothermic and larval abundance is apparently related directly to seasonal warming of bottom waters, we considered the possibility that spawning, indicated by the presence of naupliar stages in plankton hauls, might occur over a rather narrow temperature range. The yearly range in bottom temperatures decreased with an increase in depth. At the shallowest stations, temperatures ranged from 5.9° to 30.4° C., and at the deepest stations, from 16.8° to 26.2° C. In general, naupliar stages occurred over a temperature range of 17.0° to 28.5° C., but the magnitude of the range varied between depths (table 5). At 14-, 27-, 46-, and 82-m. stations the magnitude of the range where nauplii were taken was 3.8°, 11.5°, 8.5°, and 5.6° C., respectively.

DISTRIBUTION OF PLANKTONIC-STAGE SHRIMP

Areal distribution charts for each planktonic stage were made for January to March, April to August, and September to December. Values plotted at each station were obtained by averaging catches per 100 cm.³ of water filtered for

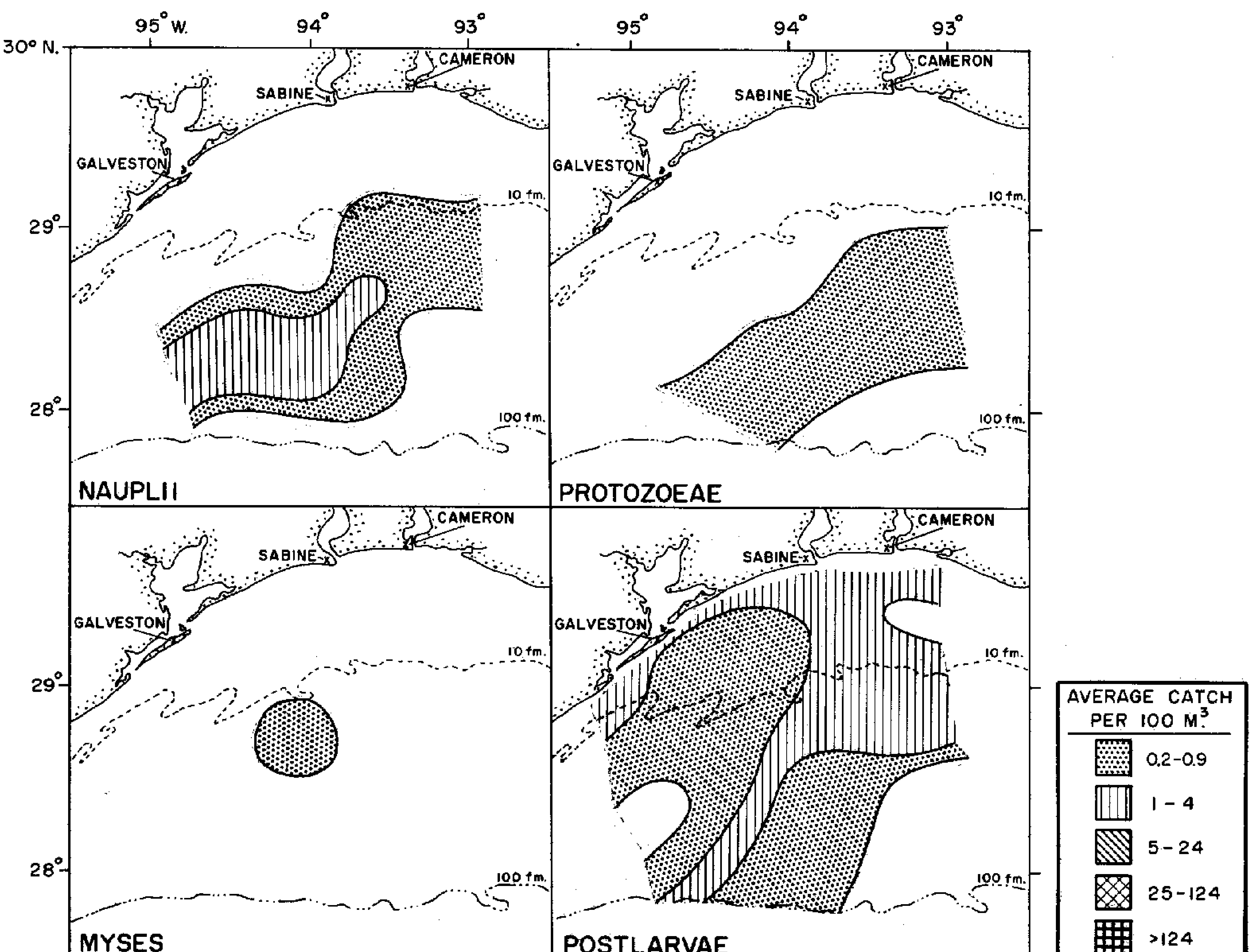


FIGURE 5.—Relative abundance and distribution of planktonic-stage *Penaeus* spp., January to March 1961.

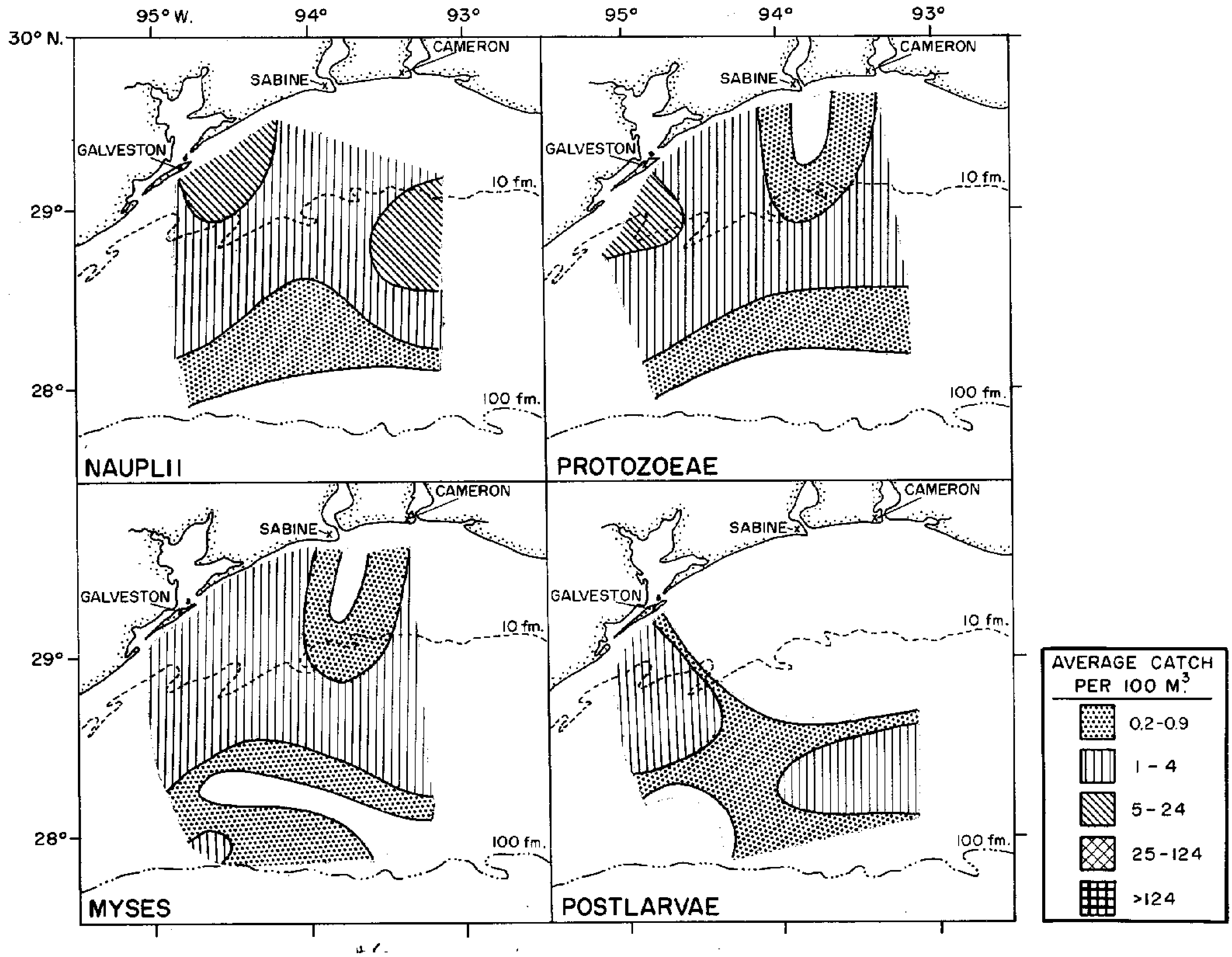


FIGURE 6.—Relative abundance and distribution of planktonic-stage *Penaeus* spp., April to August 1961.

TABLE 5.—*Yearly range in bottom temperatures and temperatures in which naupliar stages were taken in the northwestern Gulf of Mexico in 1961*

Station depth	Yearly range in temperature	Temperature in which nauplii occurred	
		Range	Magnitude of range
Meters	*° Centigrade*	*° Centigrade*	*° Centigrade*
14	5.9–30.4	24.7–28.5	3.8
27	11.9–31.0	17.0–28.5	11.5
46	14.2–27.7	19.0–27.5	8.5
82	16.8–26.2	19.9–25.5	5.6

each time period. Isopleths were then drawn to delineate areas of planktonic-stage concentrations (figs. 5, 6, and 7).

Slight shifts in the areal distribution of naupliar, protozoeal, and mysis stages were apparent. In January to March, larvae were restricted largely to waters deeper than 14 m. and shallower than 82 m.; in April to August concentrations were primarily shoreward of 46 m.; and in September to December, when the great-

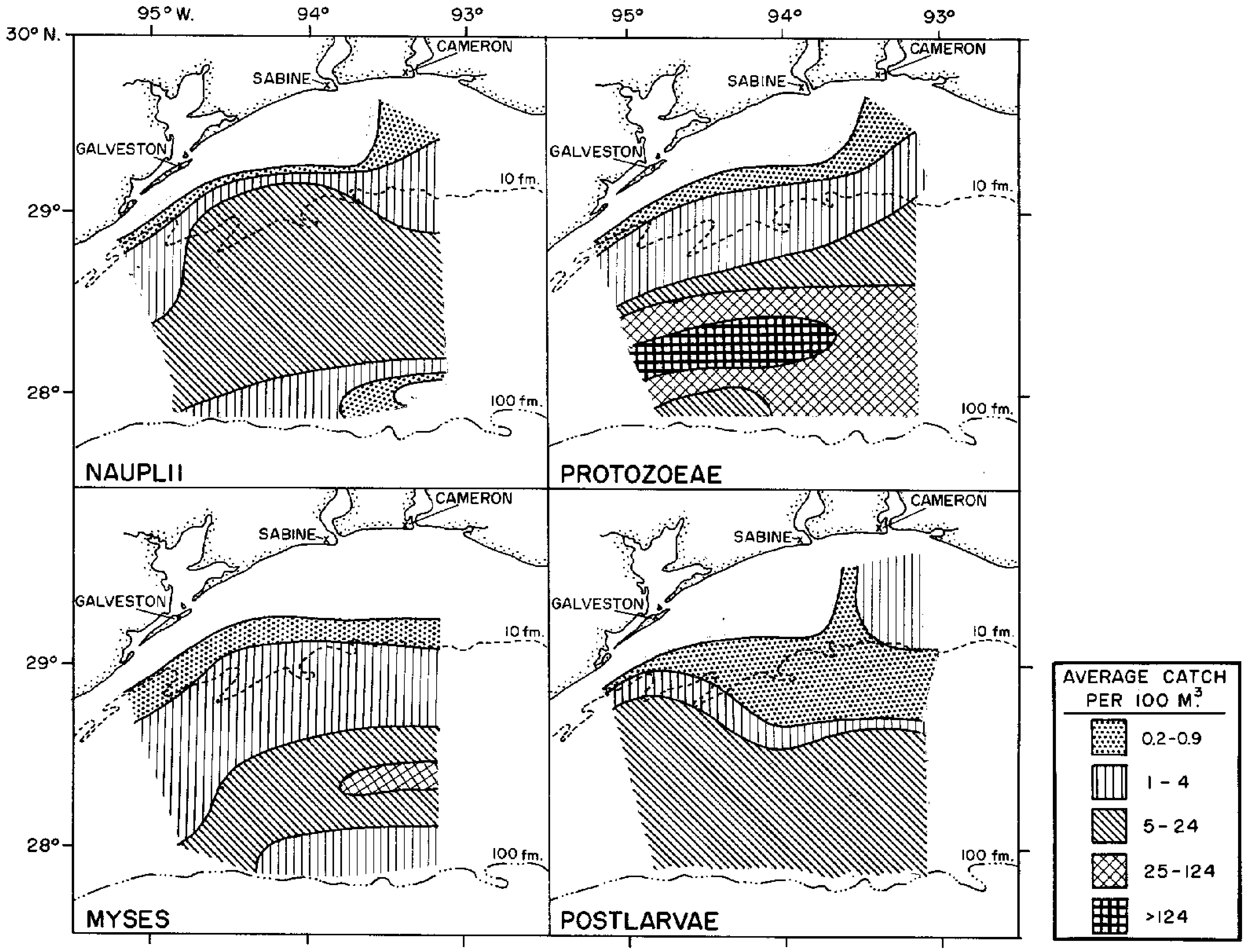
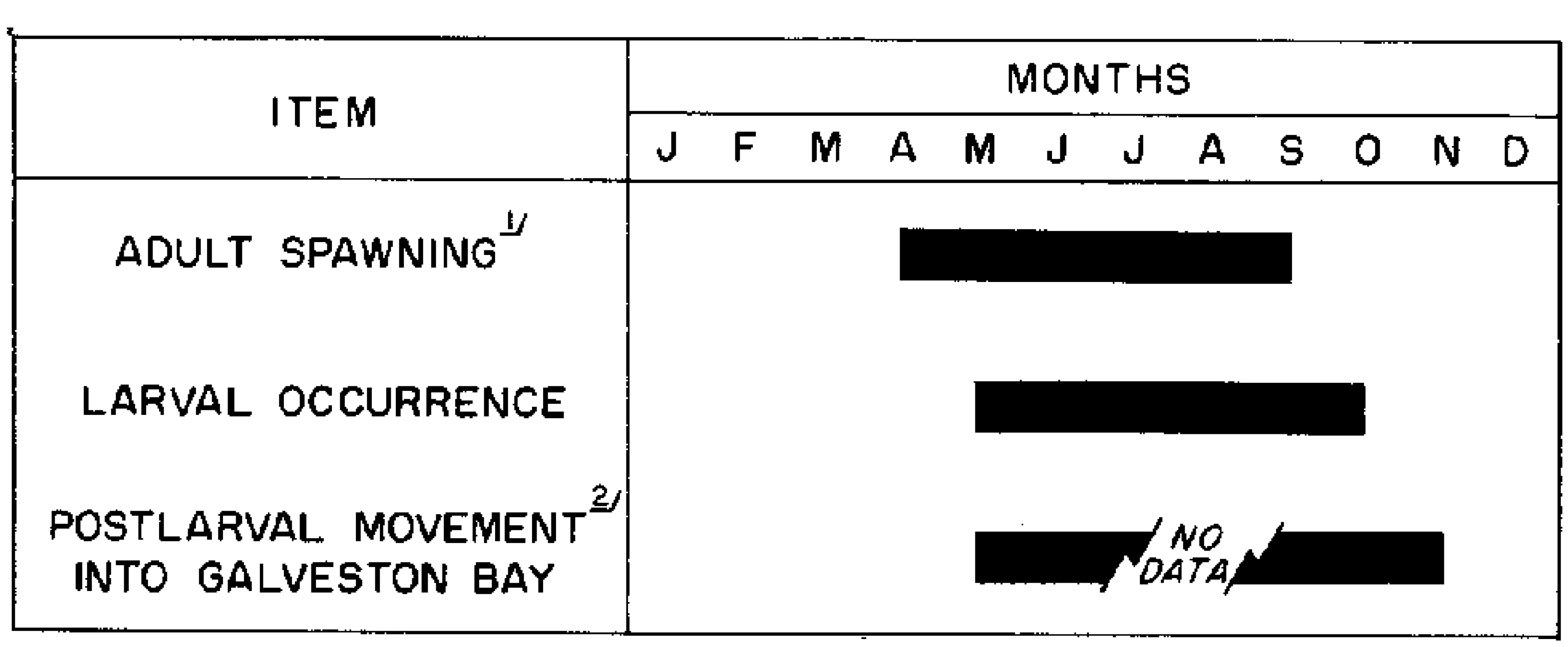


FIGURE 7.—Relative abundance and distribution of planktonic-stage *Penaeus* spp., September to December 1961.



1/ TAKEN FROM LINDNER AND ANDERSON, 1956
2/ TAKEN FROM BAXTER AND RENFRO, 1966

FIGURE 8.—Months of spawning, larval occurrence, and postlarval movement into Galveston Bay by the white shrimp, *P. setiferus*.

est number of larvae were caught, they were restricted generally to waters deeper than 14 m. The occurrence of larvae at 14-m. stations in April to August reflects, we believe, the spawning of white shrimp in shallow waters. Similarly, increased concentrations of larvae from September to December in deeper waters indicate the spawning of brown shrimp.

The areal distribution of postlarvae during the three periods differed from that of larvae.

Postlarvae occurred throughout the area in January to March, but when abundance and areal distribution of larvae were increasing in April to August, postlarval catches were generally low and postlarvae were not as widely distributed as larvae. During the ensuing months, however, the distribution of postlarvae increased, and in September to December it closely approximated that of the larval stages.

ABUNDANCE OF LARVAE AND POSTLARVAE IN RELATION TO SPAWNING PERIODS AND POSSIBLE OVERWINTERING

Although species differentiation of the larval stages of *Penaeus* spp. is impossible at this time, we have hypothesized that trends in larval abundance observed in different depths of water are the result of differences in depth and season of spawning of white and brown shrimp. The hypothesis that greatest abundance of larvae at the shallowest stations (14 m.) follows the spawning of white shrimp is compatible with the works of Pearson (1939) and Lindner and Anderson (1956). In addition, since larval development requires 2 to 3 weeks (Pearson, 1939), agreement is also close between larval occurrence at 14-m. stations and postlarval movement of white shrimp into Galveston Bay reported by Baxter and Renfro (1967). Spawning, maximum larval abundance, and postlarval movement of white shrimp into the nursery areas are apparently completed over a 7- to 8-month period within a calendar year (fig. 8).

The chronology of spawning, larval abundance, and postlarval movement of brown shrimp into Galveston Bay is not as apparent as for white shrimp. Increasing abundance of larvae at station depths of 27 m. or deeper appears to follow closely the spawning of brown shrimp reported by Renfro and Brusher. (See footnote 4.) When compared with movement into Galveston Bay reported by Baxter (1963), however, a definite anomaly is apparent (fig. 9). Most postlarvae moved into the Bay in the spring, but the largest catches of larvae in the Gulf were made in the fall. Because similar trends in larval abundance (Fischer, 1966) and postlarval movements (Baxter and Renfro, 1967) have been observed in recent years, the possibility that techniques of sampling bias the results appears to be negligible.

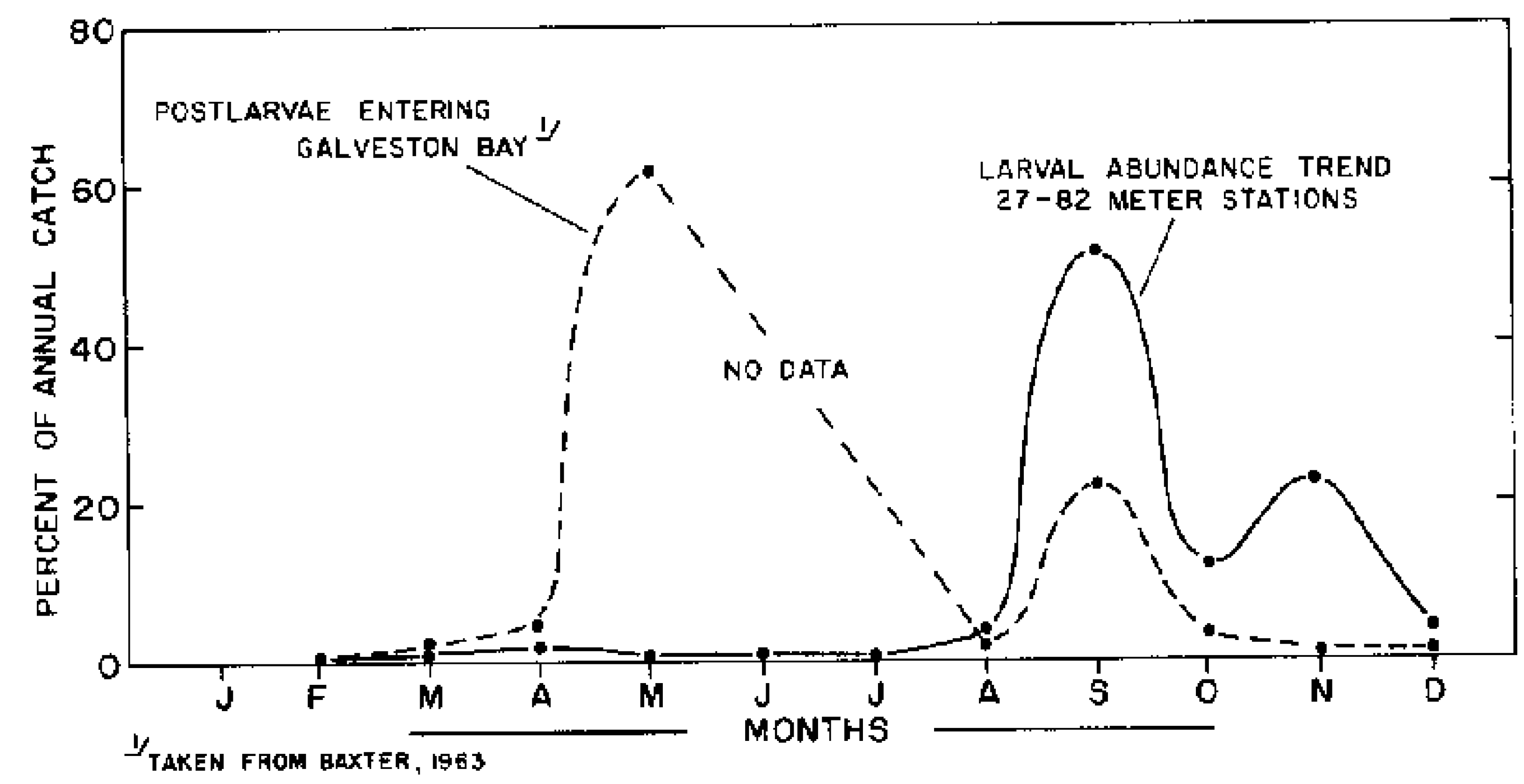


FIGURE 9.—Larval abundance trends in 27 to 82 m. of water adjacent to Galveston and postlarval movement of brown shrimp into Galveston Bay, 1961.

The difference in timing between offshore larval and inshore postlarval peaks can possibly be explained by examining seasonal abundance trends and length-frequency distributions of postlarval brown shrimp taken in plankton hauls. Postlarvae were generally taken in plankton hauls from January through April, and August through December (fig. 4). As with larvae, most postlarvae were taken in the fall. Length-frequency distributions, based on total lengths from the tip of the rostrum to the tip of the telson, reveal two distinctly different size groups (fig. 10). In January to April, most postlarvae averaged 11 to 12 mm., whereas in August to December they averaged only 6 to 7 mm.

The size difference between the two groups of postlarvae has significance when compared with length-frequency distribution of postlarvae migrating into Galveston Bay (Baxter and Renfro, 1967). Postlarval shrimp taken during the peak inshore movement average about 12 to 13 mm. in total length, and were probably represented offshore by the group of postlarvae averaging 11 to 12 mm. taken between January and April. The question still remains, however: From what spawning and peak of larval abundance did the postlarvae originate? Kutkuhn (1966) stated that the postlarvae probably originated from ". . . heightened spawning activity in offshore brown shrimp populations during February and

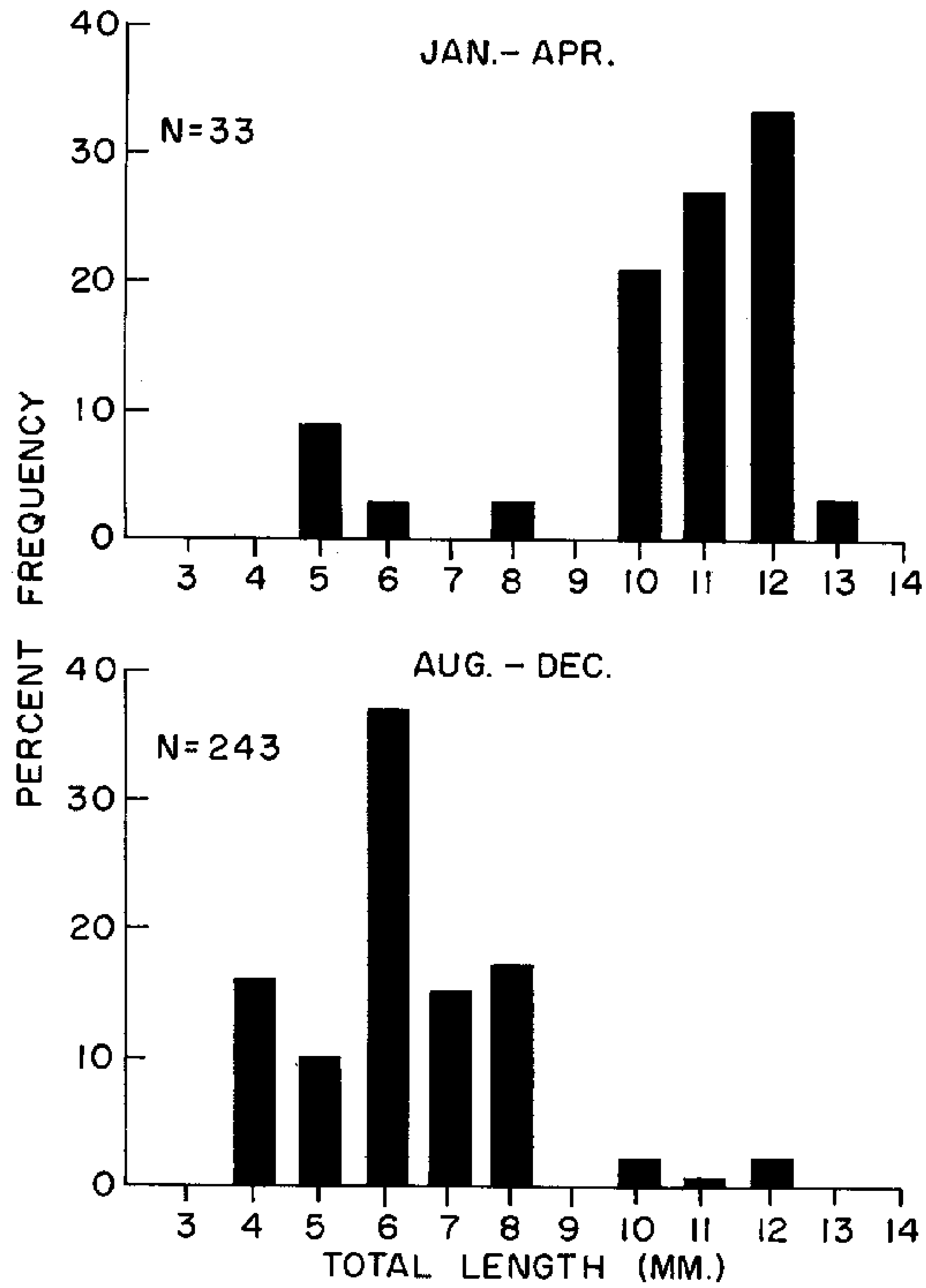


FIGURE 10.—Length-frequency distributions of postlarval brown shrimp (*P. aztecus*) taken in plankton hauls, 1961.

March. . ." Renfro and Brusher (see footnote 4), however, reported that, although brown shrimp may spawn continually throughout the year, major periods of spawning activity are in April to June and September to November. Furthermore, in the absence of large catches of larval stages during January to March 1961, the possibility arises that this spring group of postlarvae originated from a large spawning in the fall of 1960. If this is true, young brown shrimp must remain offshore either as larvae or postlarvae for a longer period than was previously suspected.

If young brown shrimp do overwinter offshore, the developmental rate of these larvae or the growth rate of the postlarvae, or both, must be slower than has been previously reported for white shrimp. Cook (1966 b), while rearing larval brown shrimp, observed retarded developmental rates at temperatures lower than 30° C. Zein-Eldin and Aldrich (1965) reported that postlarvae held in the laboratory under controlled temperature had a maximum growth rate of about 1.4 mm. per day at 32° C. and 1.1 mm. per day at 25° C. They also found that growth of postlarvae held over a 30-day period at 11° C. was practically nil, but that survival was high.

Additional support for the hypothesis that brown shrimp may overwinter before entering the nursery areas was provided by Aldrich, Wood, and Baxter.[5] They found that in the laboratory postlarval brown shrimp would burrow in response to experimentally reduced temperatures. This response usually occurred between 12° to 17° C. It appears then that under certain temperatures postlarval brown shrimp may burrow and grow at a slow rate.

Results of laboratory experiments on larval development rates, postlarval growth, and postlarval burrowing characteristics are of particular significance because temperatures similar to those tested occur in the waters over the Continental Shelf of the northwestern Gulf of Mexico (Harrington, 1965). Of even greater significance is the fact that these temperatures occur between the fall peak of larval abundance (apparently associated with brown shrimp spawning) and the peak occurrence of postlarval brown shrimp in Galveston Entrance. Additional field and laboratory work is required, however, to substantiate the hypothesis of overwintering brown shrimp larvae or postlarvae, or both, in offshore waters.

[5] "A behavioral comparison of postlarval *Penaeus aztecus* and *P. setiferus*, with regard to burrowing as a response to reduced temperatures," by David V. Aldrich, Carl E. Wood, and Kenneth N. Baxter, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex., 3 figs.

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